THE EFFECTS OF SALINITY ON THE DISTRIBUTION OF AMPHIPODS IN THE COORONG, SOUTH AUSTRALIA, IN RELATION TO THEIR SALINITY TOLERANCE

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Summary

KANGAS, M. I. & GEDDES, M. C. (1984) The effects of salinity on the distribution of amphipods in the Coorong, South Australia, in relation to their salinity tolerance. *Trans. R. Soc. S. Aust.* 108(3), 139-145, 13 December, 1984.

The tolerance of *Melita zeylanica* and *Paracorophium* sp. to a range of salinity and temperature combinations was investigated by LD_{50} analysis and response surface analysis. At the optimum temperature of 18-20°C, the salinity tolerance of both species was from 1 to 62‰; at high and low temperatures, tolerance to high salinity was reduced. *Melita zeylanica, Paracorophium* sp. and *Megamphopus* sp. were common in the Coorong, but all species generally were restricted to salinities below 53‰. No deleterious effects of salinity on the reproductive condition of populations were identified.

KEY WORDS: *Melita zeylanica, Paracorophium, Megamphopus,* salinity tolerance, amphipods, Coorong, South Australia.

Introduction

Most investigations of the salinity tolerance of estuarine and coastal marine amphipods have considered tolerance to dilute conditions (Vlasblom & Bolier 1971; Dorgelo 1974, 1976; Ritz 1980). Few studies have been made on tolerance of amphipods to concentrations greater than seawater (McLusky 1967; Marsden 1980), although amphipods are often important in hypermarine systems (Hedgpeth 1967). In the present study the salinity tolerance of *M. zeylanica* and *Paracorophium* at various temperatures were examined in the laboratory and the results related to the field distribution of the amphipod species in the Coorong lagoons. In the field study the relative abundance and reproductive status of the amphipod species are investigated to look for possible sublethal effects of salinity and temperature on amphipod populations.

The Coorong is a coastal lagoon system situated in the south east of South Australia (Fig. 1). The Coorong waters show a marked longitudinal salinity gradient which varies in direction and intensity seasonally and from year to year (Noye 1975). In 1982, the Coorong lagoons were hypersaline (Geddes & Butler, 1984), and this provided the opportunity to investigate the distribution of organisms along a hypermarine salinity gradient. Amphipods form a major part of the macrobenthic fauna and this study investigates the distribution and salinity tolerance of three common species *Melita zeylanica* Stebbing (Melitidae), *Paracorophium* sp. (Corophiidae) and *Megamphopus* sp. (Isaedidae). *Melita zeylanica* is a cosmpolitan species, commonly found in estuarine systems (Croker 1971; Barnard 1972; Griffiths 1973; Krishnan & John 1974, 1975; Boltt 1975) and has been recorded in Australia from the Peel-Inlet (Potter *et al.* 1981) and Lucky Bay, Western Australia (Barnard 1972), from the Tuggerah Lakes, New South Wales (Collett *et al.* 1981), and from the Gippsland Lakes, Victoria (Poore 1982). The other two amphipods are

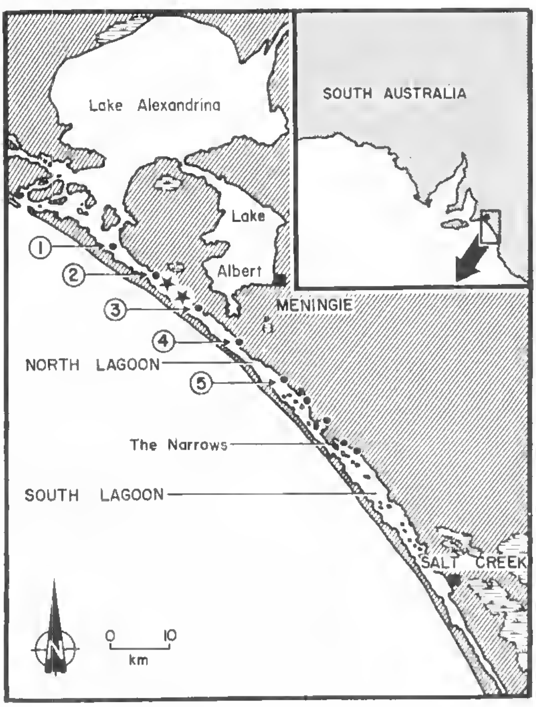

Fig. 1. The Coorong lagoons showing sampling localities (•) and sites where populations of *M. zeylanica* and *Paracorophium* sp. were collected for salinity tolerance experiments (*).

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undescribed. The genus *Paracorophium* is endemic to the Southern hemisphere and found in Australia, New Zealand and South America (Barnard & Karaman 1983). *Paracorophium* sp. differs from *P. excavatum* Chilton, the only described species known from Australia, in the structure of the third uropod and the number of setae on gnathopods 1 and 2 of the male. Very small numbers of a second undescribed species of *Paracorophium* were also collected. Neither species is similar to known *Paracorophium* species (Karaman 1979). No species of *Megamphopus* have been described from Australia (M. Drummond pers. comm.) but species have been found in abundance in the Tuggerah Lakes, N.S.W. (Collett *et al.* 1981) and the Gippsland Lakes in Victoria (M. Drummond, pers. comm.). Reference material of the species considered in this paper has been placed in the South Australian Museum, Adelaide (SAM C3924–C3927).

Materials and Methods

(i) *Salinity Tolerance*

Amphipods were collected in March, April and June 1982 from two localities (Fig. 1) at salinities of 51.3, 41.9 and 44‰ respectively.

Salinity tolerance was determined at five temperatures for hypersaline conditions (5.5, 14.4, 18.5, 26, 32.5 °C for *M. zeylanica* and 6, 14.4, 19.5, 26, 30.5 °C, for *Paracorophium* sp.) and three temperatures for dilute conditions (14, 18, 25.4 °C for *M. zeylanica* 14.4, 19.5, 27.5 °C for *Paracorophium* sp.). Amphipods were acclimated to test temperatures in 35‰ (seawater) for two days prior to experimentation.

9–12 amphipods were directly transferred to five salinity dilutions (0.1–10.5‰) and ten hypersaline media (38.5–73.9‰). Dilute media were prepared by mixing seawater and distilled water; hypermarine media were mixtures of seawater and Coorong water. Conductivities (K_{25}) were measured with a Radiometer CDM2e Conductivity Meter and total dissolved solids (TDS) calculated by a regression provided in Williams (1966). This regression was developed for saline lake waters but comparison of dried TDS for samples from the Coorong with values calculated from conductivity via the Williams equation showed very close agreement (Geddes & Butler, 1984). This is to be expected considering the similar nature of ionic dominance in Coorong water and that of Australian salt lakes (Williams & Buckney 1976). The TDS values were used as a measure of salinity.

At all salinity-temperature combinations, adult individuals were used without regard to sex. Gentle aeration and a light/dark regime of 12 hour: 12 hour was maintained but no food was added. Fine debris and filamentous algae was supplied to *Paracorophium* sp. to enable it to construct tubes (considerable mortality was experienced when this tube dwelling species was kept in clear water). The number of animals surviving were counted at 6 and 24 hours and every 24 hours thereafter for 96 hours. Following Ritz (1980), death was taken as a cessation of pleopodal rhythmic beating motor response to tactile stimulation.

Data were analysed in two ways: determining LD_{50} values and fitting response surfaces to survival data. For LD_{50} determination, the dose and response (% survival) values were transformed to log dose and logits (Hewlett & Plackett 1979) and regression equations calculated with the form $Y = a + bX$ where Y is logit + 10. This form allows symmetrical confidence limits to be placed on LD_{50} values.

The response surfaces were fitted according to a BMDP program Stepwise Logistic Regression (PLR) accessed via the Cyber 173 computer. The PLR estimates the vector of parameters (βi) for the linear logistic model $E(s/n) = e^{\beta X}/1 + e^{\beta X}$ where s is the sum of the binary dependent variable (dead, alive) and X represents the independent variables (salinity, temperature). The parameter βi may be expanded to a quadratic $\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X^2_1 + \beta_4 X^2_2 + \beta_5 X_1 X_2$ where X_1 is the temperature, X_2 is the salinity, β_0 is a constant, β_1 is the linear effect of temperature, β_2 is the linear effect of salinity, β_3 is the quadratic effect of temperature, β_4 is the quadratic effect of salinity and β_5 is the interaction effect between temperature and salinity. Contour lines for specified percent survival were then plotted.

(ii) *Field Observations*

A series of offshore stations (Fig. 1) were sampled in the North Lagoon of the Coorong at approximately monthly intervals from January 1982–March 1983. The northern end of the South Lagoon was sampled in August 1982 (Fig. 1). At each station, surface temperatures and water samples were taken. Amphipods were collected by towing a trawl net (160 μm) through algal beds for 5–10 minutes. The samples were returned to the laboratory, sorted, preserved in 10% formalin and identified. One hundred randomly selected individuals were identified to record species composition and relative abundance; within each species, sex ratio, female reproductive condition, and egg number were noted.

Results

(i) *Salinity Tolerance*

Tables 1 and 2 summarise results found through logit analysis for *M. zeylanica* and *Paracorphium* sp. respectively. The lower LD_{50} value for *M. zeylanica* and *Paracorophium* sp. is 1.0‰ and the upper LD_{50} value for *M. zeylanica* is 62‰ and for *Paracorophium* sp. is 60.5‰, indicating a wide tolerance range for each species. Due to the wide confidence limits, the respective values of LD_{50} at each temperature trial overlap with the preceding and following values. General trends are that highest LD_{50} values occur at medial temperatures while they decrease at both lower and higher temperatures. For *M. zeylanica* at 5.5°C the LD_{50} value is 52‰ and at 32.5°C is reduced to 49‰. For *Paracorophium* sp. the LD_{50} value is 59‰ at 6.0°C and 48‰ at 30.5°C.

The contour patterns for salinity-temperature combinations are shown in Fig. 2. Both species show wide temperature and salinity tolerance with greater than 90% survival over most of the experimental range. The central region in the contour pattern provides an estimate of optimum conditions (Alderice 1972). The close spacing of the contours indicates relatively low variability of response in the experimental animals.

Temperature and salinity values and the relative abundance of species at stations 1, 2, 3, 4 and 5 (Stations 1, 3, 5, 7 and 9 in Geddes & Butler, 1984) during the period December 1981–March 1983 are shown in Fig. 3. Low salinities in Dec. 1981, presumably the result of freshwater influx from Lake Alexandrina, were followed by an increase in salinity during the summer months, a lowering during April–June and an increase the following summer. At stations 4 and 5 highest recorded salinities were 68‰ and 82‰ in January 1983. Surface temperature reached 27°C in summer and the minimum was 11°C in June.

TABLE 1. *Relationship between logit + 10 of % mortality (x) and ln K_{25} (y) and the calculated LD_{50} values for* M. zeylanica *for high and low salinities and at various temperatures*

Temp.	Regression Equation	r^2	LD_{50} ± 95% confidence limits (K_{25})	LD_{50} ± 95% confidence limits (Salinity: TDS)
5.5c	$l_n y = 3.896 + 0.036\,x$	0.744	70.18 ± 14.92	51.9 ± 9.0
14.4c	$l_n y = 4.382 + 0.006\,x$	0.010	71.68 ± 75.60	53.3 ± 56.9
18.5c	$l_n y = 4.111 + 0.025\,x$	0.731	78.49 ± 16.29	61.8 ± 9.9
26.0c	$l_n y = 4.168 + 0.017\,x$	0.191	76.72 ± 35.19	58.0 ± 23.0
32.5c	$l_n y = 3.81 + 0.04\,x$	0.682	67.47 ± 18.73	49.4 ± 11.5
14.0d	$l_n y = 4.57 - 0.376\,x$	0.947	2.25 ± 6.03	1.3 ± 3.5
18.0d	$l_n y = 3.83 - 0.329\,x$	0.925	1.72 ± 6.83	1.0 ± 4.0
26.0d	$l_n y = 4.771 - 0.356\,x$	0.834	3.36 ± 28.90	1.9 ± 18.4

c—intermediate and concentrated media.
d—dilute media.

TABLE 2. *Relationship between logit + 10 of % mortality (x) and ln K_{25} (y) and the calculated LD_{50} values for* Paracorophium *sp. for high and low salinities and at various temperatures*

Temp.	Regression Equation	r^2	LD_{50} ± 95% confidence limits (K_{25})	LD_{50} ± 95% confidence limits (Salinity: TDS)
6.0c	$l_n y = 3.867 + 0.049\,x$	0.518	78.33 ± 25.81	59.5 ± 16.3
14.4c	$l_n y = 4.092 + 0.028\,x$	0.597	79.44 ± 24.6	60.5 ± 15.4
19.5c	$l_n y = 4.002 + 0.031\,x$	0.610	79.21 ± 23.45	60.3 ± 14.6
26.0c	$l_n y = 3.794 + 0.049\,x$	0.614	72.61 ± 18.26	54.1 ± 11.2
30.5	$l_n y = 3.749 + 0.044\,x$	0.789	66.07 ± 15.39	48.2 ± 9.3
15.0d	$l_n y = 4.101 - 0.476\,x$	0.536	0.52 ± 33.17	0.3 ± 21.5
18.0d	$l_n y = 4.136 - 0.476\,x$	0.576	0.54 ± 30.56	0.3 ± 19.6
27.5d	$l_n y = 4.961 - 0.442\,x$	0.640	1.72 ± 26.82	1.0 ± 17.0

c—intermediate and concentrated media.
d—dilute media.

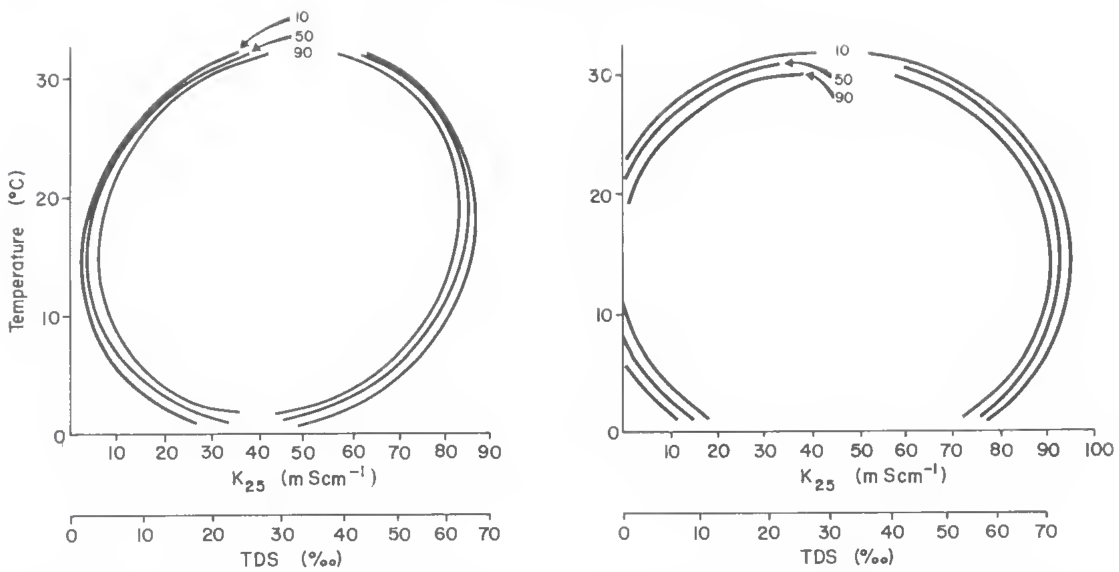

Fig. 2. Estimation of percent survival based on a fitted response surface to observed mortality at 96 hr. under 65 conditions of temperature and salinity.
(a) *M. zeylanica* ($e^{i}/1 + e^{i} = -4.695 + .237s \pm .551t - .003s^2 - .019t^2 - .391ts$).
(b) *Paracorophium* sp. ($e^{i}/1 + e^{i} = -2.183 + .18s - .002s^2 - .016t^2$).

M. zeylanica, Paracorophium and *Megamphopus* sp. were found at stations 1, 2 and 3 throughout the study period. *Paracorophium* sp. and *Megamphopus* sp. occurred at station 4 in Jan. 1982 at a salinity of 60‰, but seem to have succumbed to the increasing salinities in the following months. In Nov. and Dec. 1982 *Paracorophium* sp. reappeared after a period of lowered salinities. *Melita zeylanica* was collected from station 4 in May when salinity dropped to 51‰. *Paracorophium* sp. was the only species found at station 5 with 5 individuals collected in June. In the South Lagoon salinities were above 80‰ and no amphipods were found.

All three species maintained large populations at stations 1, 2 and 3 throughout the study period. *Paracorophium* sp. generally had the greatest relative abundance and seasonal fluctuations in the abundance of *Paracorophium* sp. were small. *M. zeylanica* occurred in higher numbers from March–June with a lowering of numbers from Feb.-April 1982 but their abundance was high from June–Nov.

Table 3 documents the effects of salinity and season on the reproductive condition of females; it compares the mean percent ovigerous females and the mean egg number per ovigerous female for the different stations in "summer" (Jan.-April 1982 and Nov. 1982–March 1983) and "winter" (June–Oct. 1982).

All three species breed throughout the year with similar numbers of ovigerous females being present during the summer and winter months. The percent ovigerous females does not show a consistent change between stations, although a substantial decrease occurs at station 4 for *Paracorophium* sp. The mean number of eggs per ovigerous female for *M. zeylanica* was similar between stations and seasons except for a low egg number at station 3 in summer. For *Paracorophium* sp. and *Megamphopus* sp. there were often significant differences in egg number between stations, with highest egg number generally recorded at station 2.

Discussion

A longitudinal gradient of increasing salinity persisted in the Coorong throughout 1982 with hypersaline conditions being maintained over most regions. In years of high River Murray flow the North Lagoon of the Coorong experiences marked lowering of salinity levels (Noye 1975) and so to persist in this region the fauna must be able to tolerate both estuarine and hypermarine conditions. This may limit species richness. In the event, amphipods in the Coorong form a simple assemblage with only three common species. In comparison, many estuaries have a much larger assemblage of amphipods (Gable & Croker 1978; Collet *et al.* 1981). Although *Melita zeylanica, Paracorophium* and *Megamphopus* are found in

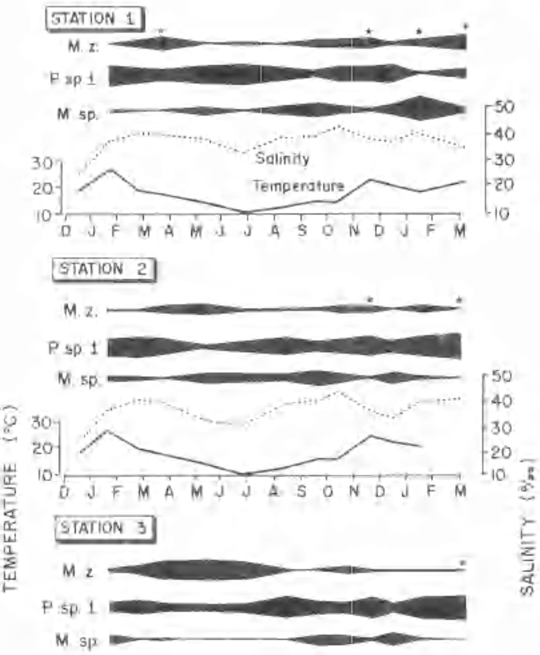

Fig. 3. Seasonal fluctuations in temperature and salinity and the relative abundance (%) of *M. zeylanica* (M.z) *Paracorophium* sp. (P.sp.1) and *Megamphopus* (M.sp.) from Dec. 1981–March 1983. * indicates times when less than 20 individuals were found in samples. P.sp.1 from station 5 is represented by an open block.

estuaries, they appear to be particularly well adapted to the extreme conditions met in coastal lagoon systems. Some or all of these three amphipods are present in other Australian coastal lagoon systems as previously indicated.

Laboratory studies on *M. zeylanica* and *Paracorophium* sp. show that they are eurythermal and euryhaline with a salinity tolerance range of 1–62‰ at the optimal temperature of 18 °C. Tolerance at temperature extremes (5 °C and 32.5 °C) was somewhat restricted but salinities of 50‰ could be tolerated at all temperatures investigated. A wide tolerance range is charateristic of estuarine or coastal lagoon species which experience fluctuations in environmental conditions (McLusky 1967, 1968; Jones 1972; Dorgelo 1976), and studies on the tolerance of two estuarine amphipods, *Orchestia chiliensis* (Marsden 1980) and *Corophium volutator* (McLusky 1967) showed a tolerance of 3–51‰ and 2–50‰ respectively. The present study, and the field records of amphipods from 50–80‰ from the Laguna Madre in North America (Hedgpeth 1967), suggest that acclimation in hypermarine environments produced higher salinity tolerance than is normal for estuarine species.

Most work using response surface analysis has involved fish and large decapods. None has involved amphipods. In the present study, response contour lines were more closely spaced than in studies on decapods and fish (Costlow *et al.* 1962; Kinne 1971; Alderice 1972) indicating little individual variability in response. This may relate to the osmotic behaviour of the decapods and fish studied which are osmoregulators, while the amphipods in the present study are probably conformers in hypermarine water. There may be more individual variability in the response of regulators to salinity stress than for conformers.

In 1982, amphipod distribution was not limited by low salinity as is the case in most estuarine systems (Meadows 1964; McLusky 1968; Mills & Fish 1980), but the field distribution of all species was limited by high salinities in the stations further from the mouth of the lagoon. Under the rather stable salinity pattern which persisted throughout 1982, no extensive changes in amphipod distribution were seen. Generally amphipods were restricted to salinities less than 53‰ although sporadic records of a few individuals were made to salinities up to 63‰. These values are somewhat lower than found in the laboratory tolerance studies. Field studies in conjunction with laboratory investigations provide information on other factors affecting distribution. One factor which may explain differences between laboratory results and field distributions is the lag time in recruitment of individuals into an area which has only recently become favourable. It is possible that amphipods were absent from southern stations in the winter months when salinities were apparently suitable because previous high summer salinities there had exceeded tolerance limits. The young have direct develop-

TABLE 3. *Comparison of percent females ovigerous and mean egg number per ovigerous female between different stations and different "seasons". Figures for percent females ovigerous based on 10-100 females and for egg number on mean of 5-75 brood pouches. The * represents significant differences between mean egg number (Student's t-test, $P<0.05$).*

Station	% Ovigerous "Summer"	% Ovigerous "Winter"	Mean # Eggs "Summer"	Mean # Eggs "Winter"
		M. zeylanica		
1	—	33.6	—	9.2
2	79.7	53.3	* 14.6	12.3
3	72.3	65.2	7.4	9.8
		Paracorophium sp.		
1	24.7	20.0	* 1.9	2.7 * *
2	50.4	25.8	* 4.8	5.8
3	32.8	35.9	4.4 *	4.9
4	6.0	—	2.0	—
		Megamphopus sp.		
1	44.5	22.7	* 4.3	4.3
2	27.5	28.7	* 7.9	5.5
3	28.0	31.0	4.2	3.9

ment and so there is no planktonic dispersal phase. Thus, in a system with seasonal and long-term fluctuations in salinity and with animals having poor dispersal abilities, it is possible that there is a time lag between the advent of suitable physico-chemical conditions in an area and the establishment of a viable population.

There were no clear effects of salinity on the reproductive condition of populations. The proportion of ovigerous females and the mean egg number per female showed no seasonal change although summer salinities were considerably higher than those in winter. At stations 1 to 3 there was no major difference in percent ovigerous females but *Paracorophium* sp. from station 4 showed a marked reduction in the percent ovigerous females. For all species there were some differences in mean egg number between stations, with stations 3 and 4 having lower egg number than station 2. This may indicate some lowering of reproductive capacity at higher salinities, but the evidence is not conclusive.

The amphipods form a major part of the macrobenthic fauna of the Coorong, and are probably important in food chains leading to fish and birds. High salinities in the Coorong results in narrowing of the range of distribution and lowering of abundance of amphipods and this may have significant effects on animals further up the food chain.

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A NEW SPECIES OF CALAMOECIA (COPEPODA: CALANOIDA) FROM SOUTH AUSTRALIA, AND COMMENTS ON THREE CONGENERS

BY I. A. E. BAYLY

Summary

Calamoecia zeidleri sp. nov., a comparatively large species of Calamoecia, is described from fresh waters near Lake Eyre and Oodnadatta.